

**Course Title:** Radiological Control Technician  
**Module Title:** Unit Analysis & Conversion  
**Module Number:** 1.02

**Objectives :**

- 1.02.01 Identify the commonly used unit systems of measurement and the base units for mass, length, and time in each system.
- 1.02.02 Identify the values and abbreviations for SI prefixes.
- 1.02.03 Given a measurement and the appropriate conversion factor(s) or conversion factor table, convert the measurement to the specified units.
- 1.02.04 Using the formula provided, convert a given temperature measurement to specified units.

**INTRODUCTION**

A working knowledge of the unit analysis and conversion process is necessary for the Radiological Control Technician. It is useful for air and water sample activity calculations, contamination calculations, and many other applications. This lesson will introduce the International System of Units (SI), the prefixes used with SI units, and the unit analysis and conversion process. Many calculations accomplished in radiological control are actually unit conversions, not complex calculations involving formulas that must be memorized.

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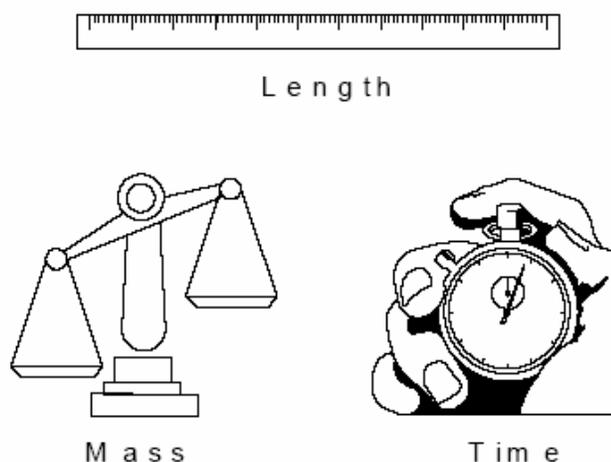
## UNITS AND MEASUREMENTS

Units are used in expressing physical quantities or *measurements*, i.e., length, mass, etc. All measurements are actually relative in the sense that they are comparisons with some standard unit of measurement. Two items are necessary to express these physical quantities: a number which expresses the magnitude and a unit which expresses the dimension. A number and a unit must both be present to define a measurement. Measurements are algebraic quantities and as such may be mathematically manipulated subject to algebraic rules.

### Fundamental Quantities

All measurements or physical quantities can be expressed in terms of three fundamental quantities. They are called fundamental quantities because they are dimensionally independent. They are:

- *Length* (L)
- *Mass* (M) (not the same as weight)
- *Time* (T)



**Figure 1. Fundamental Units**

### Derived Quantities

Other quantities are derived from the fundamental quantities. These *derived* quantities are formed by multiplication and/or division of fundamental quantities. For example:

- Area is the product of *length* times *length* (width), which is  $L \times L$ , or  $L^2$ .
- Volume is area times length, which is *length* times *length* times *length*, or  $L^3$ .
- Velocity is expressed in *length* per unit *time*, or  $L/T$ .
- Density is expressed in *mass* per unit volume, or  $M/L^3$ .

1.02.01 *Identify the commonly used unit systems of measurements and the base units for mass, length, and time in each system.*

## SYSTEMS OF UNITS

The units by which physical quantities are measured are established in accordance with an agreed standard. Measurements made are thereby based on the original standard which the unit represents. The various units that are established, then, form a *system* by which all measurements can be made.

### English System

The system that has historically been used in the United States is the English System, sometimes called the English Engineering System (EES). Though no longer used in England, many of the units in this system have been used for centuries and were originally based on common objects or human body parts, such as the foot or yard. Though practical then, the standards for these units were variable as the standard varied from object to object, or from person to person. The base units for length, mass, and time in the English system are the foot, pound, and second, respectively.

Even though fixed standards have since been established for these antiquated units, no uniform correlation exists between units established for the same quantity. For example, in measuring relatively small lengths there are inches, feet, and yards. There are twelve inches in a foot, and yet there are only three feet in a yard. This lack of uniformity makes conversion from one unit to another confusing as well as cumbersome. However, in the U.S., this system is still the primary system used in business and commerce.

**Table 1. English System Base Units**

<b>Physical Quantity</b>	<b>Unit</b>	<b>Abbr.</b>
<b>Length:</b>	foot	ft.
<b>Mass:</b>	pound	lb.
<b>Time:</b>	second	sec.

## **International System of Units (SI)**

Since the exchange of scientific information is world-wide today, international committees have been set up to standardize the names and symbols for physical quantities. In 1960, the **International System of Units** (abbreviated SI from the French name *Le Système Internationale d'Unites*) was adopted by the 11th General Conference of Weights and Measures (CGPM). The SI, or modernized **metric system**, is based on the decimal (base 10) numbering system. First devised in France around the time of the French Revolution, the metric system has since been refined and expanded so as to establish a practical system of units of measurement suitable for adoption by all countries. The SI system consists of a set of specifically defined units and prefixes that serve as an internationally accepted system of measurement. Nearly all countries in the world use metric or SI units for business and commerce as well as for scientific applications.

1.02.02      *Identify the values and abbreviations for SI prefixes.*

### **SI Prefixes**

The SI system is completely decimalized and uses prefixes for the base units of *meter* (m) and *gram* (g), as well as for derived units, such as the *liter* (l) which equals  $1000 \text{ cm}^3$ .

SI prefixes are used with units for various magnitudes associated with the measurement being made. Units with a prefix whose value is a positive power of ten are called *multiples*. Units with a prefix whose value is a negative power of ten are called *submultiples*.

For example, try using a yard stick to measure the size of a frame on film for a camera. Instead you would use inches, because it is a more suitable unit. With the metric system, in order to measure tiny lengths, such as film size, the prefix *milli-* can be attached to the meter unit to make a millimeter, or 1/1000 of a meter. A millimeter is much smaller and is ideal in this situation. On the other hand, we would use a prefix like *kilo-* for measuring distances traveled in a car. A *kilometer* would be more suited for these large distances than the meter.

Table 2. SI Prefixes

PREFIX	FACTOR	SYMBOL	PREFIX	FACTOR	SYMBOL
yotta	$10^{24}$	Y	deci	$10^{-1}$	d
zetta	$10^{21}$	Z	centi	$10^{-2}$	c
exa	$10^{18}$	E	milli	$10^{-3}$	m
peta	$10^{15}$	P	micro	$10^{-6}$	$\mu$
tera	$10^{12}$	T	nano	$10^{-9}$	n
giga	$10^9$	G	pico	$10^{-12}$	p
mega	$10^6$	M	femto	$10^{-15}$	f
kilo	$10^3$	k	atto	$10^{-18}$	a
hecto	$10^2$	h	zepto	$10^{-21}$	z
deka	$10^1$	da	yocto	$10^{-24}$	y

Prior to the adoption of the SI system, two groups of units were commonly used for the quantities length, mass, and time: **MKS** (for meter-kilogram-second) and **CGS** (for centimeter-gram-second).

Table 3. Metric Subsystems

Physical Quantity	CGS	MKS
<b>Length:</b>	centimeter	meter
<b>Mass:</b>	gram	kilogram
<b>Time:</b>	second	second

### SI Units

There are seven fundamental physical quantities in the SI system. These are length, mass, time, temperature, electric charge, luminous intensity, and molecular quantity (or amount of substance). In the SI system there is one SI unit for each physical quantity. The SI system base units are those in the metric MKS system. Table 4 lists the seven fundamental quantities and their associated SI unit. The units for these seven fundamental quantities provide the base from which the units for other physical quantities are derived.

For most applications the RCT will only be concerned with the first four quantities as well as the quantities derived from them.

### **Radiological Units**

In the SI system, there are derived units for quantities used for radiological control. These are the becquerel, the gray, and the sievert. The SI unit of activity is the becquerel, which is the activity of a radionuclide decaying at the rate of one spontaneous nuclear transition per second. The gray is the unit of absorbed dose, which is the energy per unit mass imparted to matter by ionizing radiation, with the units of one joule per kilogram. The unit for dose equivalence is the sievert, which has the units of joule per kilogram. These quantities and their applications will be discussed in detail in Lesson 1.06.

**Other units**

There are several other SI derived units that are not listed in Table 4. It should be noted that the SI system is evolving and that there will be changes from time to time. The standards for some fundamental units have changed in recent years and may change again as technology improves our ability to measure even more accurately.

Table 4. International System (SI) Units

Physical Quantity	Unit	Symbol	Dimensions
<i>Base units</i>			
<b>Length:</b>	meter	m	m
<b>Mass:</b>	kilogram	kg	kg
<b>Time:</b>	second	s or sec.	s
<b>Temperature:</b>	kelvin	K	K or °K
<b>Electric current:</b>	ampere	A or amp	A or (C/s)
<b>Luminous intensity:</b>	candela	cd	cd
<b>Molecular quantity:</b>	mole	mol	mol
<i>Selected derived units</i>			
<b>Volume:</b>	cubic meter	m <sup>3</sup>	m <sup>3</sup>
<b>Force:</b>	newton	N	kg≅m/s <sup>2</sup>
<b>Work/Energy:</b>	joule	J	N≅m
<b>Power:</b>	watt	W	J/s
<b>Pressure:</b>	pascal	Pa	N/m <sup>2</sup>
<b>Electric charge:</b>	coulomb	C	A≅s
<b>Electric potential:</b>	volt	V	J/C
<b>Electric resistance:</b>	ohm	Σ	V/A
<b>Frequency:</b>	hertz	Hz	s <sup>-1</sup>
<b>Activity:</b>	becquerel	Bq	disintegration/s
<b>Absorbed dose:</b>	gray	Gy	J/kg
<b>Dose equivalence:</b>	sievert	Sv	Gy≅Q≅N

1.02.03      *Given a measurement and the appropriate conversion factor(s) or conversion factor table, convert the measurement to the specified units.*

## UNIT ANALYSIS AND CONVERSION PROCESS

### Units and the Rules of Algebra

Remember that a measurement consists of a number and a unit. When working problems with measurements, it should be noted that the measurement units are subject to the same algebraic rules as the values. Some examples are provided below.

$$(cm) \times (cm) = cm^2$$

$$\frac{ft^3}{ft} = ft^2$$

$$\frac{1}{yr} = yr^{-1}$$

As a result, measurements can be multiplied, divided, etc., in order to convert to a different system of units. Obviously, in order to do this, the units must be the same. For example, a square measures one foot in length and 18 inches in width. To find the area of the square in square inches we must multiply the length by the width. However, when the measurements are in different units, and cannot be multiplied directly.

We can convert feet to inches. We know that there are 12 inches in one foot. We can use this ratio to convert 1 foot to 12 inches. Then we can then calculate the area as 12 inches  $\times$  18 inches, which equals 216 in<sup>2</sup>, which is a valid measurement.

### Steps for Unit Analysis and Conversion

- 1) Determine given unit(s) and desired unit(s).
- 2) Build (or obtain) conversion factor(s) -- see Conversion Tables at end of lesson

A conversion factor is a ratio of two equivalent physical quantities expressed in different units. *When expressed as a fraction, the value of all conversion factors is 1.* Because a conversion factor equals 1, it does not matter which value is placed in the numerator or denominator of the fraction.

Examples of conversion factors are:

$$\frac{365\text{days}}{1\text{year}} \quad \frac{12\text{inches}}{1\text{foot}} \quad \frac{1\text{foot}^3}{2.832\text{E}4\text{cm}^3}$$

Building conversion factors involving the metric prefixes for the same unit can be tricky. This involves the conversion of a base unit to, or from, a subunit or superunit.

To do this, use the following steps: Example: 1 gram to milligrams

a) Place the base unit in the numerator and the subunit/ superunit in the denominator (or vice versa):

$$\frac{g}{mg}$$

b) Place a 1 in front of the subunit/superunit:

$$\frac{g}{1mg}$$

c) Place the value of the prefix on the subunit/ superunit in front of the base unit:

$$m \text{ (milli-)} = 10^{-3} \text{ or } 1\text{E}$$

$$\frac{1\text{E} - 3g}{1mg}$$

Also remember that algebraic manipulation can be used when working with metric prefixes and bases. For example, 1 centimeter =  $10^{-2}$  meters. This means that 1 meter =  $1/10^{-2}$  centimeters, or 100 cm. Therefore, the two conversion factors below are equal:

$$\frac{1\text{E} - 2m}{1cm} = \frac{1m}{100cm}$$

3) Set up an equation by multiplying the given units by the conversion factor(s) to obtain desired unit(s).

When a measurement is multiplied by a conversion factor, the unit(s) (and probably the magnitude) will change; however, the actual measurement itself does not change. For example, 1 ft and 12 inches are still the same length; only different units are used to express the measurement.

By using a "ladder" or "train tracks," a series of conversions can be accomplished in order to get to the desired unit(s). By properly arranging the numerator and denominator of the conversion factor(s), given and intermediate units will cancel

out by multiplication or division, leaving the desired units. Some examples of the unit analysis and conversion process follow:

**EXAMPLE 1.**

Convert 3 years to seconds.

Step 1 - Determine given and desired unit(s):

Given units: years

Desired units: seconds.

Step 2 - Build/obtain conversion factor(s):

We can use multiple conversion factors to accomplish this problem:

1 year = 365.25 days

1 day = 24 hours

1 hour = 60 minutes

1 minute = 60 seconds

Step 3 - Analyze and cancel given and intermediate units. Perform multiplication and division of numbers:

$$\left(\frac{3\text{years}}{1}\right)\left(\frac{365.25\text{days}}{1\text{year}}\right)\left(\frac{24\text{hours}}{1\text{day}}\right)\left(\frac{60\text{minutes}}{1\text{hour}}\right)\left(\frac{60\text{seconds}}{1\text{minute}}\right) = 94,672,800 \text{ sec.}$$

unit analysis and conversion process follow:

**EXAMPLE 2.**

What is the activity of a solution in  $\frac{\mu\text{Ci}}{\text{ml}}$  if it has 2000  $\frac{\text{dpm}}{\text{gallon}}$  ?

Step 1 - Determine given and desired unit(s):

Given units:  $\frac{\text{dpm}}{\text{gallon}}$

Desired units:  $\frac{\mu\text{Ci}}{\text{ml}}$

Step 2 - Build conversion factor(s):

1 liter = 0.26418 gallons

1 dpm = 4.5 E-07  $\mu\text{Ci}$

1 liter = 1000 ml

Step 3 - Analyze and cancel given and intermediate units. Perform multiplication and division of numbers.

$$\left(\frac{2000\text{dpm}}{\text{gal}}\right)\left(\frac{4.5\text{E}-7\mu\text{Ci}}{1\text{dpm}}\right)\left(\frac{0.26418\text{gal}}{1\ell}\right)\left(\frac{1\ell}{1,000\text{ml}}\right) = 2.38\text{E}-7\frac{\mu\text{Ci}}{\text{ml}}$$

Practical exercises and their solutions are provided at the end of this lesson.

1.02.04	Using the formula provided, convert a given temperature measurement to specified units.
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## TEMPERATURE MEASUREMENTS AND CONVERSIONS

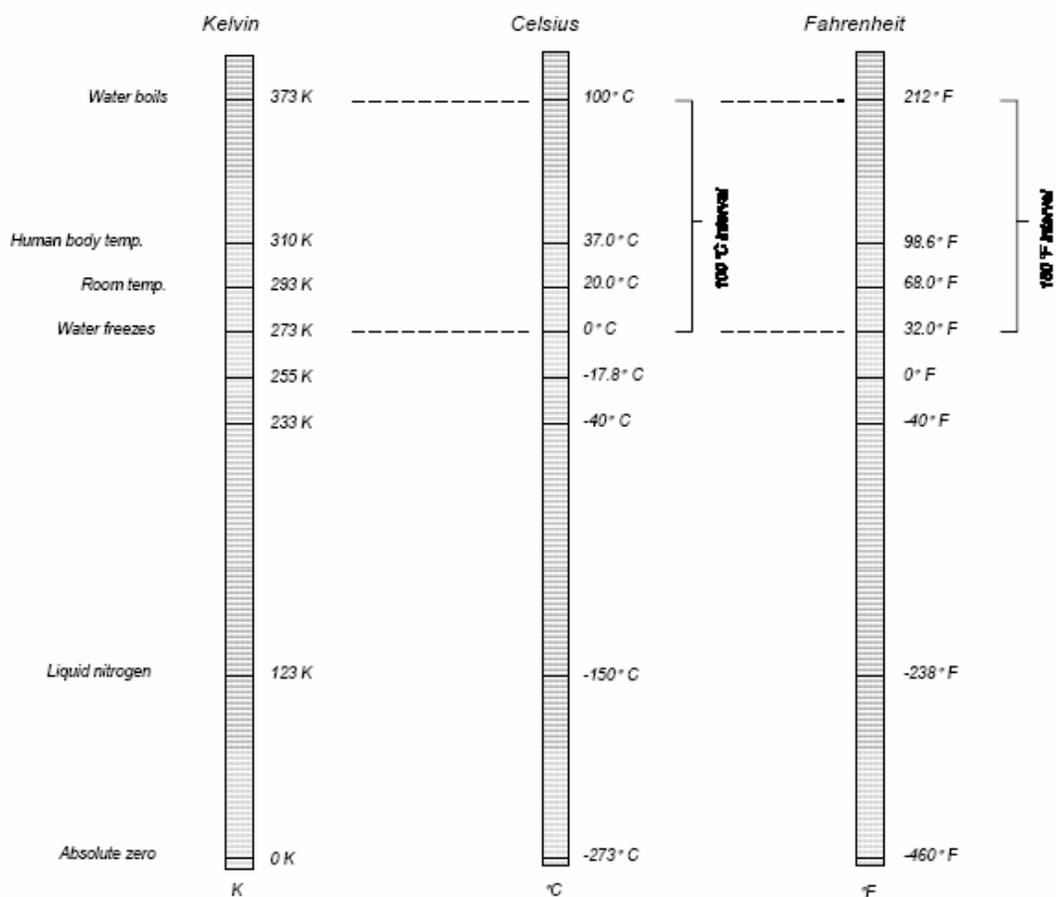
Temperature measurements are made to determine the amount of heat flow in an environment. To measure temperature it is necessary to establish relative scales of comparison. Three temperature scales are in common use today. The general temperature measurements we use on a day-to-day basis in the United States are based on the **Fahrenheit** scale. In science, the **Celsius** scale and the **Kelvin** scale are used. Figure 2 shows a comparison of the three scales.

The Fahrenheit scale, named for its developer, was devised in the early 1700's. This scale was originally based on the temperatures of human blood and salt-water, and later on the freezing and boiling points of water. Today, the Fahrenheit scale is a secondary scale defined with reference to the other two scientific scales. The symbol °F is used to represent a degree on the Fahrenheit scale.

About thirty years after the Fahrenheit scale was adopted, Anders Celsius, a Swedish astronomer, suggested that it would be simpler to use a temperature scale divided into one hundred degrees between the freezing and boiling points of water. For many years his scale was called the **centigrade** scale. In 1948 an international conference of scientists re-named it the Celsius scale in honor of its inventor. The Celsius degree, °C, was defined as 1/100 of the temperature difference between the freezing point and boiling point of water.

In the 19th century, an English scientist, Lord Kelvin, established a more fundamental temperature scale that used the lowest possible temperature as a reference point for the beginning of the scale. The lowest possible temperature, sometimes called *absolute zero*, was established as 0 K (zero Kelvin). This temperature is 273.15°C below zero, or -273.15°C. Accordingly, the Kelvin degree, K, was chosen to be the same as a Celsius degree so that there would be a simple relationship between the two scales.

Note that the degree sign (°) is not used when stating a temperature on the Kelvin scale. Temperature is stated simply as Kelvin (K). The Kelvin was adopted by the 10th Conference of Weights and Measures in 1954, and is the SI unit of thermodynamic temperature. Note that the degree Celsius (°C) is the SI unit for expressing Celsius temperature and temperature intervals. The temperature interval one degree Celsius equals one kelvin exactly. Thus, 0°C = 273.15 K by definition.



**Figure 2. Comparison of Kelvin, Celsius and Fahrenheit scales.**

To convert from one unit system to another, the following formulas are used:

**Table 5. Equations for Temperature Conversions**

°F to °C	$^{\circ}\text{C} = \frac{(^{\circ}\text{F} - 32)}{1.8} \quad \text{or} \quad ^{\circ}\text{C} = (^{\circ}\text{F} - 32) \left( \frac{5}{9} \right)$
°C to °F	$^{\circ}\text{F} = 1.8(^{\circ}\text{C}) + 32 \quad \text{or} \quad ^{\circ}\text{F} = \left( \frac{9}{5} \right) (^{\circ}\text{C}) + 32$
°C to K	$\text{K} = ^{\circ}\text{C} + 273.15$

**EXAMPLE 3.**

Convert 65° Fahrenheit to Celsius.

$$^{\circ}\text{C} = \frac{(65^{\circ}\text{F} - 32)}{1.8}$$

$$^{\circ}\text{C} = \frac{33}{1.8}$$

$$^{\circ}\text{C} = 18.3^{\circ}\text{C}$$

**PRACTICAL EXERCISES:**

Convert the following measurements:

1. 67 mm = \_\_\_\_\_ feet.
2. 1843 ounces = \_\_\_\_\_ kg.
3. 3500 microsieverts ( $\mu\text{Sv}$ ) = \_\_\_\_\_ millirem (mrem).
4. 0.007 years = \_\_\_\_\_ minutes.
5. 5000 disintegrations per minute (dpm) = \_\_\_\_\_ millicuries (mCi).

6. 2350 micrometer ( $\mu\text{m}$ ) = \_\_\_\_\_ inches.

7.  $2.5\text{E-}4$  ergs = \_\_\_\_\_ keV.

8. 205 EF = \_\_\_\_\_ K.

9.  $2\text{E-}3$  rad = \_\_\_\_\_ milligray (mGy).

10.  $!25$  EC = \_\_\_\_\_ EF.



**PRACTICAL EXERCISE SOLUTIONS:**

1. 67 mm = \_\_\_\_\_ feet.

$$\left(\frac{67\text{mm}}{1}\right)\left(\frac{1\text{m}}{1\text{E}3\text{mm}}\right)\left(\frac{3.2808\text{ft}}{1\text{m}}\right) = 0.22\text{ft}$$

2. 1843 ounces = \_\_\_\_\_ kg.

$$\left(\frac{1843\text{oz}}{1}\right)\left(\frac{28.35\text{g}}{1}\text{oz}\right)\left(\frac{1\text{kg}}{1\text{E}3\text{g}}\right) = 52.25\text{kg}$$

3. 3500 microsieverts (
- $\mu\text{Sv}$
- ) = \_\_\_\_\_ millirem (mrem).

$$\left(\frac{3.5\text{E}3\mu\text{Sv}}{1}\right)\left(\frac{1\text{Sv}}{1\text{E}6\mu\text{Sv}}\right)\left(\frac{1\text{E}2\text{rem}}{1\text{Sv}}\right)\left(\frac{1\text{E}3\text{mrem}}{1\text{rem}}\right) = 3.5\text{E}2\text{mrem} = 350\text{mrem}$$

4. 0.007 years = \_\_\_\_\_ minutes.

$$\left(\frac{0.007\text{year}}{1}\right)\left(\frac{365.25}{1\text{year}}\right)\left(\frac{24\text{hours}}{1\text{day}}\right)\left(\frac{60\text{minutes}}{1\text{hour}}\right) = 3681.72\text{minutes}$$

5. 5000 dis./min. = \_\_\_\_\_ millicuries (mCi).

$$\left(\frac{5\text{E}3\text{dis}}{\text{min}}\right)\left(\frac{1\text{Ci}}{2.22\text{E}12\frac{\text{dis}}{\text{min}}}\right)\left(\frac{1\text{E}3\text{mCi}}{1\text{ci}}\right) = 2.25\text{E}-6\text{mCi}$$

6. 2350 micrometer ( $\mu\text{m}$ ) = \_\_\_\_\_ inch.

$$\left(\frac{2350\mu}{1}\right)\left(\frac{3.937E-5\text{inches}}{1\mu}\right) = 0.0925\text{inches} = 9.25E-2\text{inch}$$

7.  $2.5E-4$  ergs = \_\_\_\_\_ keV.

$$\left(\frac{2.5E-4\text{ergs}}{1}\right)\left(\frac{6.2148E11}{1\text{erg}}\right)\left(\frac{1\text{keV}}{1E3\text{eV}}\right) = 1.55E5\text{keV}$$

8. 205 EF = \_\_\_\_\_ K.

$$^{\circ}\text{C} = \frac{(205^{\circ}\text{F} - 32)}{1.8} = 96.1^{\circ}\text{C}$$

$$K = 96.1^{\circ}\text{C} + 273.16 = 369.27K$$

9.  $2E-3$  rad = \_\_\_\_\_ milligray (mGy).

$$\left(\frac{2E-3\text{rad}}{1}\right)\left(\frac{0.01\text{Gy}}{1\text{rad}}\right)\left(\frac{1E3\text{mGys}}{1\text{Gy}}\right) = 2E-2\text{mGy} = 0.02\text{mGy}$$

10.  $-25$  EC = \_\_\_\_\_ EF.

$$^{\circ}\text{F} = (-25^{\circ}\text{C})1.8 + 32 = -13^{\circ}\text{F}$$

Use unit analysis and conversion to solve the following:

11. Light travels at 186,000 miles per second. How many feet will light travel in one minute?

$$\left(\frac{186,000 \text{ miles}}{\text{sec}}\right)\left(\frac{5280 \text{ ft}}{1 \text{ mile}}\right)\left(\frac{60 \text{ sec}}{1 \text{ minute}}\right) = 5.89E10 \frac{\text{ft}}{\text{min}}$$

12. A worker earns a monthly salary of \$2500. If the worker gets paid every two weeks and works no overtime, what will be the gross amount for a given pay period?

$$\left(\frac{2500 \text{ dollars}}{\text{months}}\right)\left(\frac{12 \text{ months}}{1 \text{ year}}\right)\left(\frac{1 \text{ year}}{52 \text{ weeks}}\right)\left(\frac{2 \text{ weeks}}{\text{payperiod}}\right) = 1153.85 \frac{\text{dollars}}{\text{payperiod}}$$

13. An air sampler has run for 18 hours, 15 minutes at 60 liters per minute. When collected and analyzed the sample reads 7685 dis./min. What is the concentration of the sample in microcuries/cm<sup>3</sup>?

$$\left(\frac{15 \text{ minutes}}{1}\right)\left(\frac{1 \text{ hour}}{60 \text{ minutes}}\right) = 0.25 \text{ hour}$$

$$18 \text{ hours} + 0.25 \text{ hours} = 18.25 \text{ hours}$$

$$\left(\frac{18.25 \text{ hours}}{1}\right)\left(\frac{60 \text{ minutes}}{1 \text{ hour}}\right)\left(\frac{60 \text{ l}}{1 \text{ minute}}\right) = 65,700 \text{ l}$$

$$\left(\frac{7685 \text{ dpm}}{6.57E4 \text{ l}}\right)\left(\frac{1 \text{ Ci}}{2.22E12 \text{ dpm}}\right)\left(\frac{1E6 \mu\text{Ci}}{1 \text{ Ci}}\right)\left(\frac{1 \text{ l}}{1E3 \text{ ml}}\right)\left(\frac{0.99997 \text{ ml}}{1 \text{ cc}}\right) = 5.26E-11 \frac{\mu\text{Ci}}{\text{cc}}$$

**INSTRUCTIONS FOR USING CONVERSION FACTOR TABLES**

The tables that follow include conversion factors that are useful to the RCT. They are useful in making a single conversion from one unit to another by using the guide arrows at the top of the page in accordance with the direction of the conversion. However, when using the tables to develop equivalent fractions for use in unit analysis equations, a better understanding of how to read the conversion factors given in the table is required.

The conversions in the table have been arranged by section in the order of fundamental units, followed by derived units:

Length  
 Mass  
 Time  
 Area  
 Volume  
 Density  
 Radiological  
 Energy  
 Fission  
 Miscellaneous (Temperature, etc.)

The easiest way to read a conversion from the table is done as follows. Reading *left to right*, "one (1) of the units in the left column is equal to the number in the center column of the unit in the right column." For example, look at the first conversion listed under **Length**. This conversion would be read from left to right as "1 angstrom is equal to E-8 centimeters," or

$$1\text{\AA} = 10^{-8} \text{ centimeters} \Rightarrow \frac{1\text{\AA}}{10^{-8} \text{ centimeters}}$$

Another conversion would be read from left to right as "1 millimeter (mm) is equal to 1E-1 centimeters," or  $1\text{ mm} = 0.1\text{ cm}$ . This method can be applied to any of the conversions listed in these tables when reading *left to right*.

If reading *right to left*, the conversion should be read as "one (1) of the unit in the right column is equal to the inverse of (1 over) the number in the center column of the unit in the left column." For example, using the conversion shown previously, the conversion reading right to left would be "1 inch is equal to the inverse of 3.937E-5 (1/3.937E-5) micrometers," or

$$1\text{ inch} = \frac{1}{3.937E-5\mu\text{m}} = 2.54E4\mu\text{m}$$

<b>Multiply # of to obtain # of</b>	<b>by by</b>	<b>to obtain # of Divide # of</b>
	<b><u>Length</u></b>	
angstroms (Å)	$10^{-8}$	cm
Å	$10^{-10}$	m
micrometer ( $\mu\text{m}$ )	$10^{-3}$	mm
$\mu\text{m}$	$10^{-4}$	cm
$\mu\text{m}$	$10^{-6}$	m
$\mu\text{m}$	$3.937 \times 10^{-5}$	in.
mm	$10^{-1}$	cm
cm	0.3937	in.
cm	$3.2808 \times 10^{-2}$	ft
cm	$10^{-2}$	m
m	39.370	in.
m	3.2808	ft
m	1.0936	yd
m	$10^{-3}$	km
m	$6.2137 \times 10^{-4}$	miles
km	0.62137	miles
mils	$10^{-3}$	in.
mils	$2.540 \times 10^{-3}$	cm
in.	$10^3$	mils
in.	2.5400	cm
ft	30.480	cm
rods	5.500	yd
miles	5280	ft
miles	1760	yd
miles	1.6094	km

<b>Multiply # of to obtain # of</b>	<b>by by</b>	<b>to obtain # of Divide # of</b>
	<b><u>Mass</u></b>	
mg	$10^{-3}$	g
mg	$3.527 \times 10^{-5}$	oz avdp
mg	$1.543 \times 10^{-2}$	grains
g	$3.527 \times 10^{-2}$	oz avdp
g	$10^{-3}$	kg
g	980.7	dynes
g	$2.205 \times 10^{-3}$	lb
kg	2.205	lb
kg	0.0685	slugs
kg	$9.807 \times 10^5$	dynes
lb	$4.448 \times 10^5$	dynes
lb	453.592	g
lb	0.4536	kg
lb	16	oz avdp
lb	0.0311	slugs
dynes	$1.020 \times 10^{-3}$	g
dynes	$2.248 \times 10^{-6}$	lb
u (unified-- $^{12}\text{C}$ scale)	$1.66043 \times 10^{-27}$	kg
amu (physical-- $^{16}\text{O}$ scale)	$1.65980 \times 10^{-27}$	kg
oz	28.35	g
oz	$6.25 \times 10^{-2}$	lb

Note: Mass to energy conversions under miscellaneous

<b>Multiply # of to obtain # of</b>	<b>by by</b>	<b>to obtain # of Divide # of</b>
<b><u>Time</u></b>		
days	86,400	sec
days	1440	min
days	24	hours
years	$3.15576 \times 10^7$	sec
years	525,960	min
years	8766	hr
years	365.25	days
<b><u>Area</u></b>		
barns	$10^{-24}$	$\text{cm}^2$
circular mils	$7.854 \times 10^{-7}$	$\text{in.}^2$
$\text{cm}^2$	$10^{24}$	barns
$\text{cm}^2$	0.1550	$\text{in.}^2$
$\text{cm}^2$	$1.076 \times 10^{-3}$	$\text{ft}^2$
$\text{cm}^2$	$10^{-4}$	$\text{m}^2$
$\text{ft}^2$	929.0	$\text{cm}^2$
$\text{ft}^2$	144	$\text{in.}^2$
$\text{ft}^2$	$9.290 \times 10^{-2}$	$\text{m}^2$
$\text{in.}^2$	6.452	$\text{cm}^2$
$\text{in.}^2$	$6.944 \times 10^{-3}$	$\text{ft}^2$
$\text{in.}^2$	$6.452 \times 10^{-4}$	$\text{m}^2$
$\text{m}^2$	1550	$\text{in.}^2$
$\text{m}^2$	10.76	$\text{ft}^2$
$\text{m}^2$	1.196	$\text{yd}^2$
$\text{m}^2$	$3.861 \times 10^{-7}$	sq mi

<b>Multiply # of to obtain # of</b>	<b>by by</b>	<b>to obtain # of Divide # of</b>
	<b><u>Volume</u></b>	
cm <sup>3</sup> (cc)	0.99997	ml
cm <sup>3</sup>	$6.1023 \times 10^{-2}$	in. <sup>3</sup>
cm <sup>3</sup>	$10^{-6}$	m <sup>3</sup>
cm <sup>3</sup>	$9.9997 \times 10^{-4}$	liters
cm <sup>3</sup>	$3.5314 \times 10^{-5}$	ft <sup>3</sup>
m <sup>3</sup>	35.314	ft <sup>3</sup>
m <sup>3</sup>	$2.642 \times 10^2$	gal
m <sup>3</sup>	$9.9997 \times 10^2$	liters
in. <sup>3</sup>	16.387	cm <sup>3</sup>
in. <sup>3</sup>	$5.787 \times 10^{-4}$	ft <sup>3</sup>
in. <sup>3</sup>	$1.639 \times 10^{-2}$	liters
in. <sup>3</sup>	$4.329 \times 10^{-3}$	gal
ft <sup>3</sup>	$2.832 \times 10^{-2}$	m <sup>3</sup>
ft <sup>3</sup>	7.481	gal
ft <sup>3</sup>	28.32	liters
ft <sup>3</sup>	1728	in. <sup>3</sup>
gal (U.S.)	231.0	in. <sup>3</sup>
gal	0.13368	ft <sup>3</sup>
liters	33.8147	fluid oz
liters	1.05671	quarts
liters	0.26418	gal
gm moles (gas)	22.4	liters (s.t.p.)

<b>Multiply # of to obtain # of</b>	<b>by by</b>	<b>to obtain # of Divide # of</b>
<b><u>Density</u></b>		
cm <sup>3</sup> /g	$1.602 \times 10^{-2}$	ft <sup>3</sup> /lb
ft <sup>3</sup> /lb	62.43	cm <sup>3</sup> /g
g/cm <sup>3</sup>	62.43	lb/ft <sup>3</sup>
lb/ft <sup>3</sup>	$1.602 \times 10^{-2}$	g/cm <sup>3</sup>
lb/in. <sup>3</sup>	27.68	g/cm <sup>3</sup>
lb/gal	0.1198	g/cm <sup>3</sup>
<b><u>Radiological Units</u></b>		
becquerel	$2.703 \times 10^{-11}$	curies
curies	$3.700 \times 10^{10}$	dis/sec
curies	$2.220 \times 10^{12}$	dis/min
curies	10 <sup>3</sup>	millicuries
curies	10 <sup>6</sup>	microcuries
curies	10 <sup>12</sup>	picocuries
curies	10 <sup>-3</sup>	kilocuries
curies	$3.700 \times 10^{10}$	becquerel
dis/min	$4.505 \times 10^{-10}$	millicuries
dis/min	$4.505 \times 10^{-7}$	microcuries
dis/sec	$2.703 \times 10^{-8}$	millicuries
dis/sec	$2.703 \times 10^{-5}$	microcuries
kilocuries	10 <sup>3</sup>	curies
microcuries	$3.700 \times 10^4$	dis/sec
microcuries	$2.220 \times 10^6$	dis/min
millicuries	$3.700 \times 10^7$	dis/sec
millicuries	$2.220 \times 10^9$	dis/min
R	$2.58 \times 10^{-4}$	C/kg of air
R	1	esu/cm <sup>3</sup> of air (s.t.p.)
R	$2.082 \times 10^9$	ion prs/cm <sup>3</sup> of air (s.t.p.)

<b>Multiply # of to obtain # of</b>	<b>by by</b>	<b>to obtain # of Divide # of</b>
<b><u>Radiological Units (continued)</u></b>		
R	$1.610 \times 10^{12}$	ion prs/g of air
R (33.7 eV/ion pr.)	$7.02 \times 10^4$	MeV/cm <sup>3</sup> of air (s.t.p.)
R (33.7 eV/ion pr.)	$5.43 \times 10^7$	MeV/g of air
R (33.7 eV/ion pr.)	86.9	ergs/g of air
R (33.7 eV/ion pr.)	$2.08 \times 10^{-6}$	g-cal/g of air
R (33.7 eV/ion pr.)	.98	ergs/g of soft tissue
rads	0.01	gray
rads	0.01	J/kg
rads	100	ergs/g
rads	$8.071 \times 10^4$	MeV/cm <sup>3</sup> or air (s.t.p.)
rads	$6.242 \times 10^7$	MeV/g
rads	$10^{-5}$	watt-sec/g ion prs/cm <sup>3</sup> of air (s.t.p.)
rads (33.7 eV/ion pr.)	$2.39 \times 10^9$	rad
gray	100	rad
rem	0.01	sievert
sievert	100	rem
$\mu\text{Ci}^3$ ( $\mu\text{Ci/ml}$ )	$2.22 \times 10^{12}$	dpm/m <sup>3</sup>
$\mu\text{Ci/cm}^3$	$2.22 \times 10^9$	dpm/liter
dpm/m <sup>3</sup>	0.4505	pCi/m <sup>3</sup>
<b><u>Energy</u></b>		
Btu	$1.0548 \times 10^3$	joules (absolute)
Btu	0.25198	kg-cal
Btu	$1.0548 \times 10^{10}$	ergs
Btu	$2.930 \times 10^{-4}$	kW-hr
Btu/lb	0.556	g-cal/g
eV	$1.6021 \times 10^{-12}$	ergs

<b>Multiply # of to obtain # of</b>	<b>by by</b>	<b>to obtain # of Divide # of</b>
<b><u>Energy (continued)</u></b>		
eV	$1.6021 \times 10^{-19}$	joules (abs)
eV	$10^{-3}$	keV
eV	$10^{-6}$	MeV
ergs	$10^{-7}$	joules (abs)
ergs	$6.2418 \times 10^5$	MeV
ergs	$6.2418 \times 10^{11}$	eV
ergs	1.0	dyne-cm
ergs	$9.480 \times 10^{-11}$	Btu
ergs	$7.375 \times 10^{-8}$	ft-lb
ergs	$2.390 \times 10^{-8}$	g-cal
ergs	$1.020 \times 10^{-3}$	g-cm
gm-calories	$3.968 \times 10^{-3}$	Btu
gm-calories	$4.186 \times 10^7$	ergs
joules (abs)	$10^7$	ergs
joules (abs)	0.7376	ft-lb
joules (abs)	$9.480 \times 10^{-4}$	Btu
g-cal/g	1.8	Btu/lb
kg-cal	3.968	Btu
kg-cal	$3.087 \times 10^3$	ft-lb
ft-lb	1.356	joules (abs)
ft-lb	$3.239 \times 10^{-4}$	kg-cal
kW-hr	$2.247 \times 10^{19}$	MeV
kW-hr	$3.60 \times 10^{13}$	ergs
MeV	$1.6021 \times 10^{-6}$	ergs

Note: Mass to energy conversions under miscellaneous

Multiply # of to obtain # of	by by	to obtain # of Divide # of
	<b><u>Fission</u></b>	
Btu	$1.28 \times 10^{-8}$	grams $^{235}\text{U}$ fissioned <sup>b</sup>
Btu	$1.53 \times 10^{-8}$	grams $^{235}\text{U}$ destroyed <sup>b,c</sup>
Btu	$3.29 \times 10^{13}$	fissions
fission of 1 g $^{235}\text{U}$	1	megawatt-days
fissions	$8.9058 \times 10^{-18}$	kilowatt-hours
fissions <sup>b</sup>	$3.204 \times 10^{-4}$	ergs
kilowatt-hours	$2.7865 \times 10^{17}$	$^{235}\text{U}$ fission neutrons average thermal neutron flu× in fuel <sup>b,d</sup>
kilowatts per kilogram $^{235}\text{U}$	$2.43 \times 10^{10}$	% U atoms fissioned <sup>e</sup>
megawatt-days per ton U	$1.174 \times 10^{-4}$	average thermal neutron flu× in fuel <sup>b</sup>
megawatts per ton U	$2.68 \times 10^{10}/E^f$	neutrons/cm <sup>2</sup>
neutrons per kilobarn	$1 \times 10^{21}$	fissions/sec
watts	$3.121 \times 10^{10}$	

<sup>b</sup> At 200 MeV/fission.<sup>c</sup> Thermal neutron spectrum ( $\alpha = 0.193$ ).<sup>d</sup>  $\bar{\nu}$ (fission = 500 barns).<sup>e</sup> At 200 MeV fission, in  $^{235}\text{U}$ - $^{238}\text{U}$  mixture of low  $^{235}\text{U}$  content.<sup>f</sup> E = enrichment in grams  $^{235}\text{U}$ /gram total. No other fissionable isotope present.

<b>Multiply # of to obtain # of</b>	<b>by by</b>	<b>to obtain # of Divide # of</b>
	<b><u>Miscellaneous</u></b>	
radians	57.296	degrees
eV	$1.78258 \times 10^{-33}$	grams
eV	$1.07356 \times 10^{-9}$	u
erg	$1.11265 \times 10^{-21}$	grams
proton masses	938.256	MeV
neutron masses	939.550	MeV
electron masses	511.006	keV
u (amu on $^{12}\text{C}$ scale)	931.478	MeV

**Temperature**

$$^{\circ}\text{C} = \frac{(^{\circ}\text{F} - 32)}{1.8}$$

$$^{\circ}\text{F} = 1.8(^{\circ}\text{C}) + 32$$

$$^{\circ}\text{K} = ^{\circ}\text{C} + 273.16$$

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32) \left( \frac{5}{9} \right)$$

$$^{\circ}\text{F} = \left( \frac{9}{5} \right) (^{\circ}\text{C}) + 32$$

**Wavelength to Energy Conversion**

$$\text{keV} = 12.40/\text{\AA}$$

$$\text{eV} = 1.240 \times 10^{-6}/\text{m}$$